Time-variant, non-stationary Vehicle-to-Vehicle Channel Model

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Introduction V2X Channel Models

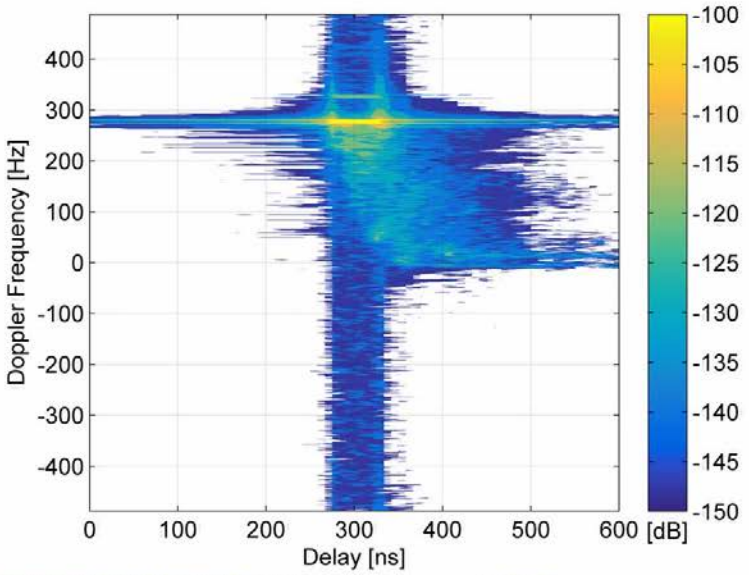
- Realistic and efficient channel models needed for performance evaluation of Next Generation V2X in IEEE NGV SG [1],[2]
- Small-scale fading models
  - Acosta-Marum channel model [3]
  - Channel models from the ETSI Plugtests™ 2013 [4],[5],[6]

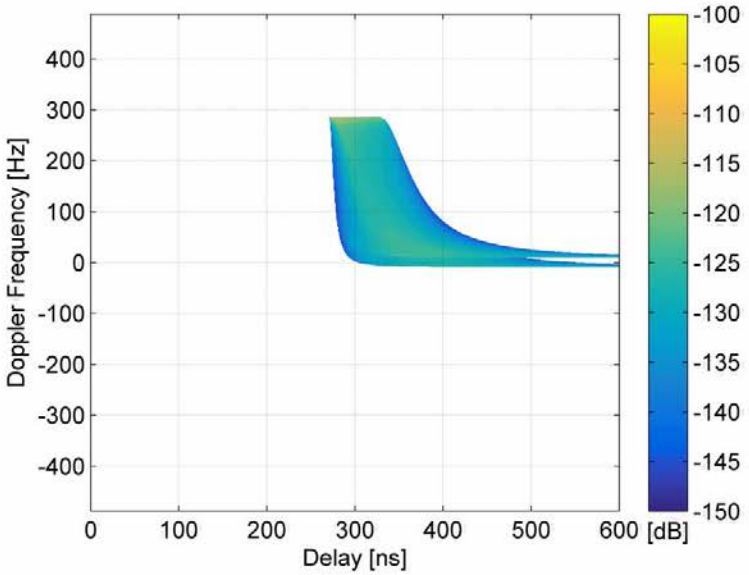
  ➔ Stochastic channel models:
  Wide-sense stationary uncorrelated scattering (WSSUS)

  Vehicular channel [6],[7]:
  Highly time-variant, correlated scatterers
- Geometry-based stochastic channel models (GSCMs)

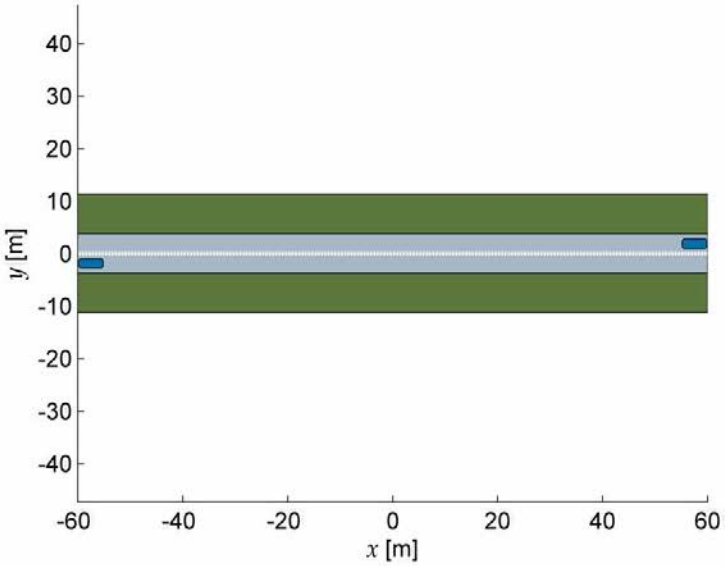
  Computational complexity

➔ GSCM with analytic delay-dependent Doppler spectra [7],[8],[9],[10]

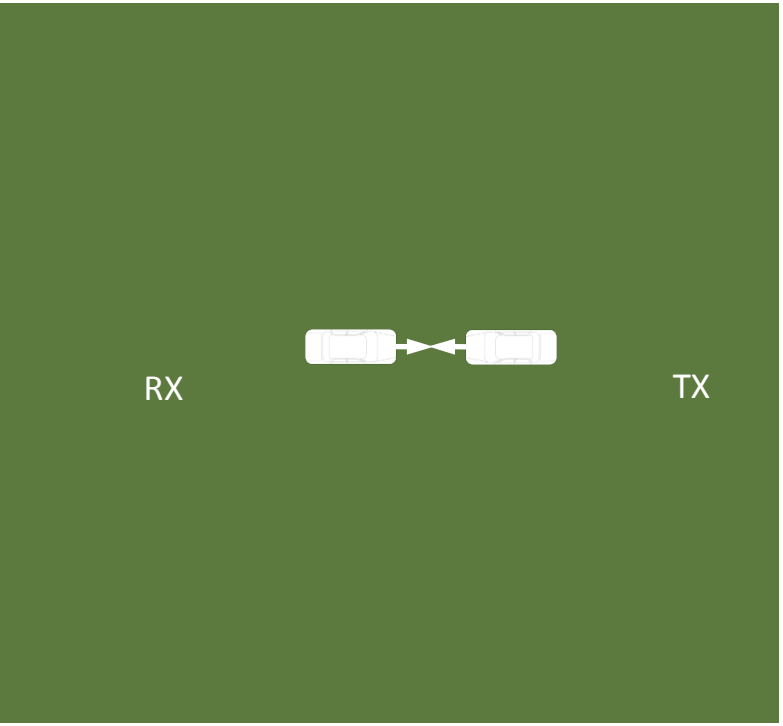

Doppler Frequency [Hz]
Delay [ns]
[dB]


Doppler Frequency [Hz]
Delay [ns]
[dB]


MIC OFF
DR500GW-HD/720P


y [m]
x [m]

V2V-Channel: Driving in Opposite Directions



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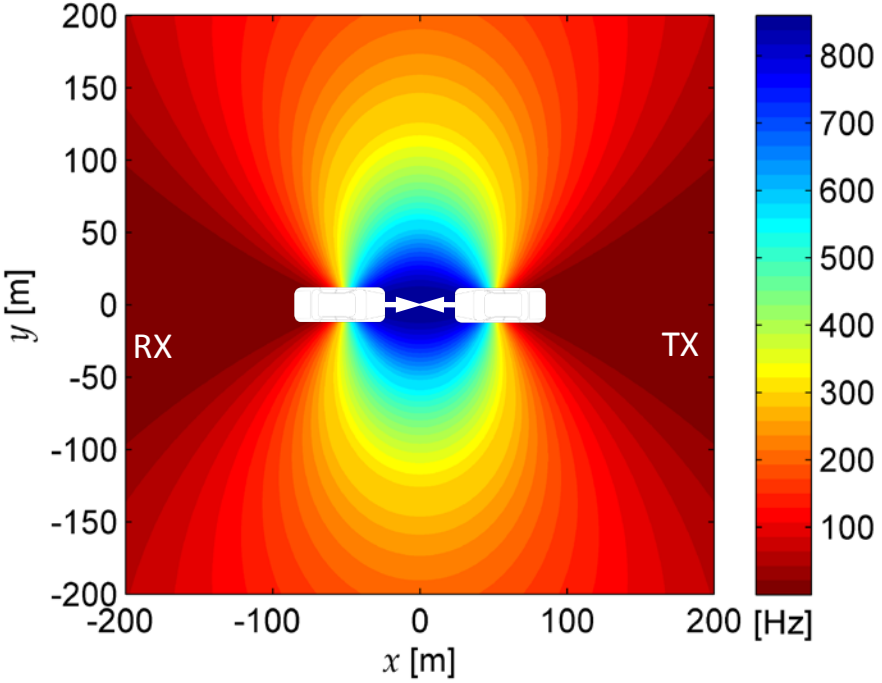

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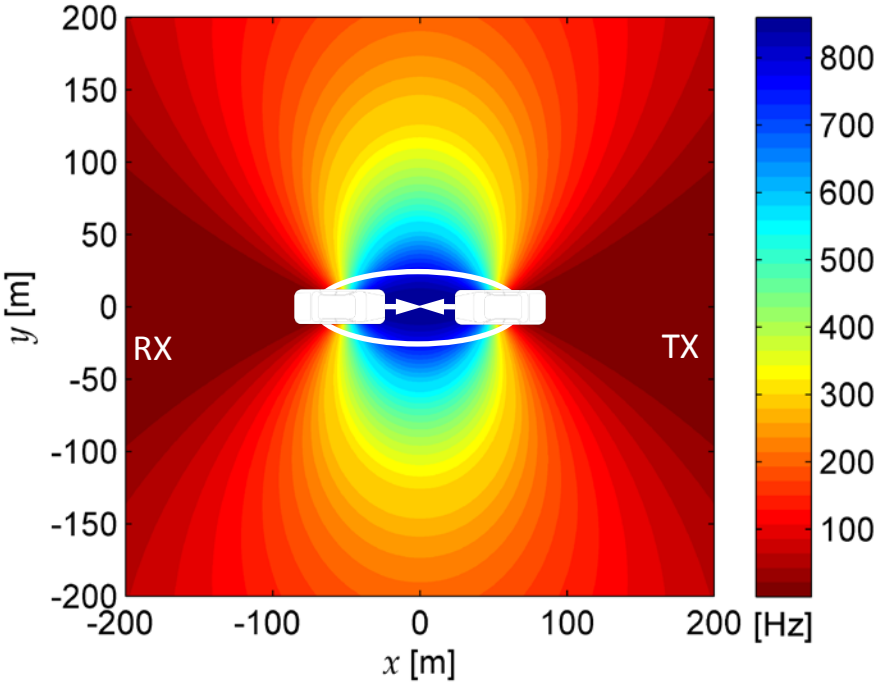

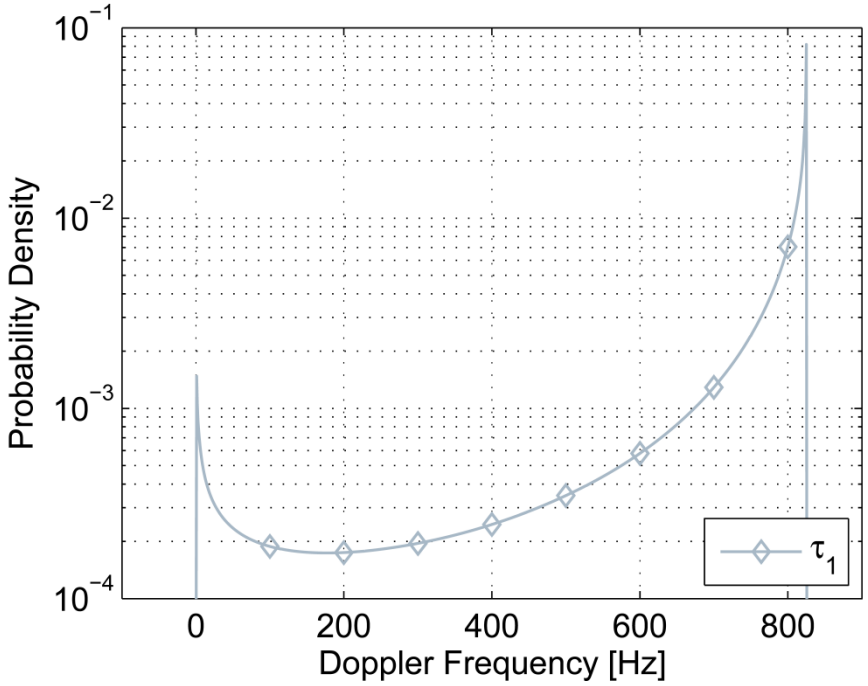

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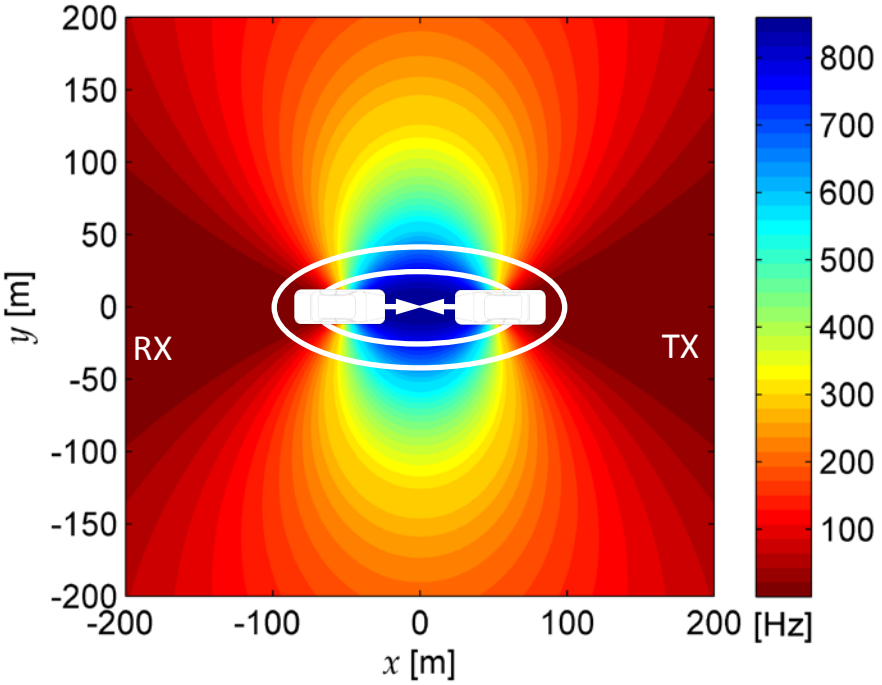

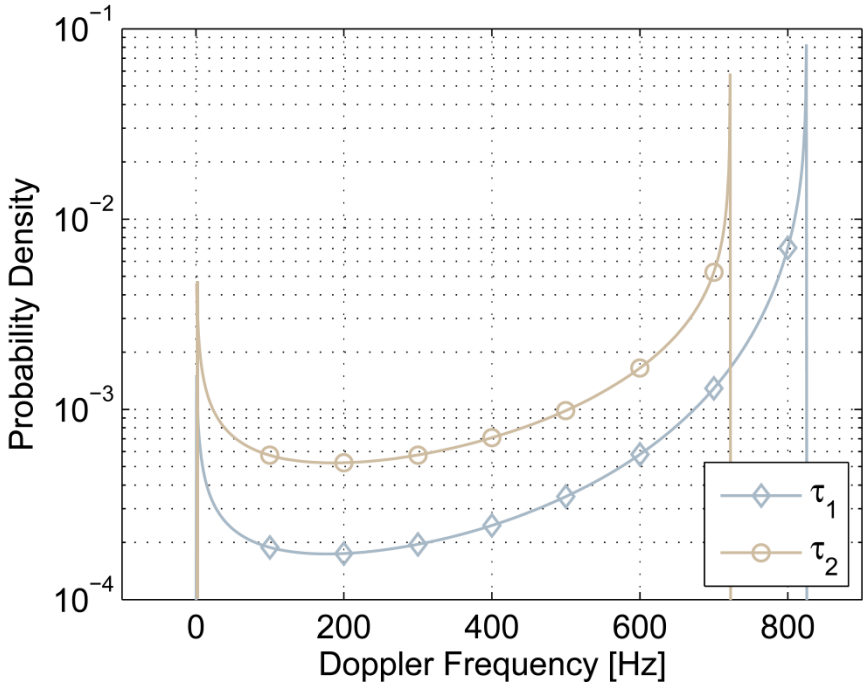

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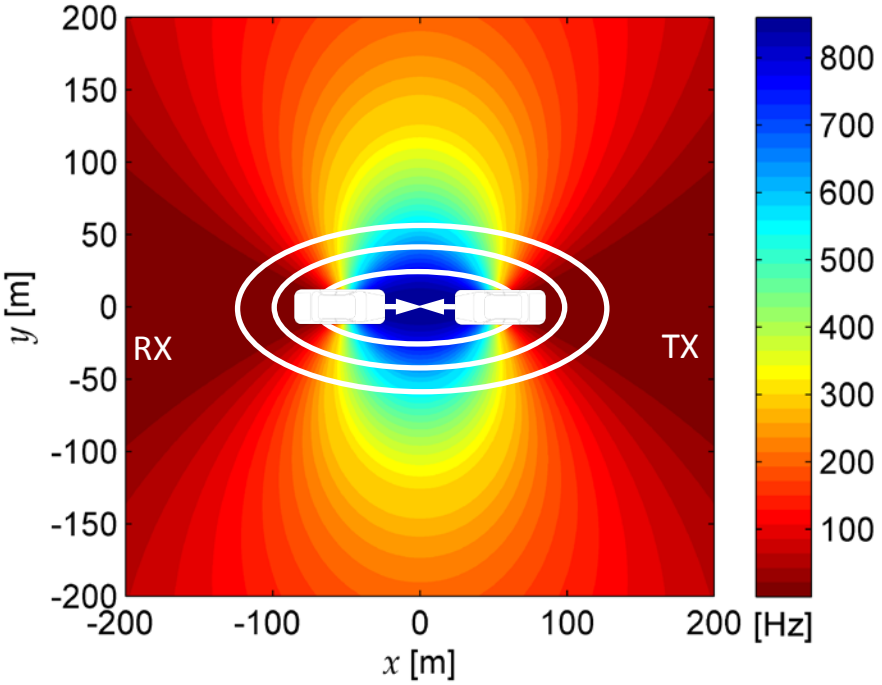

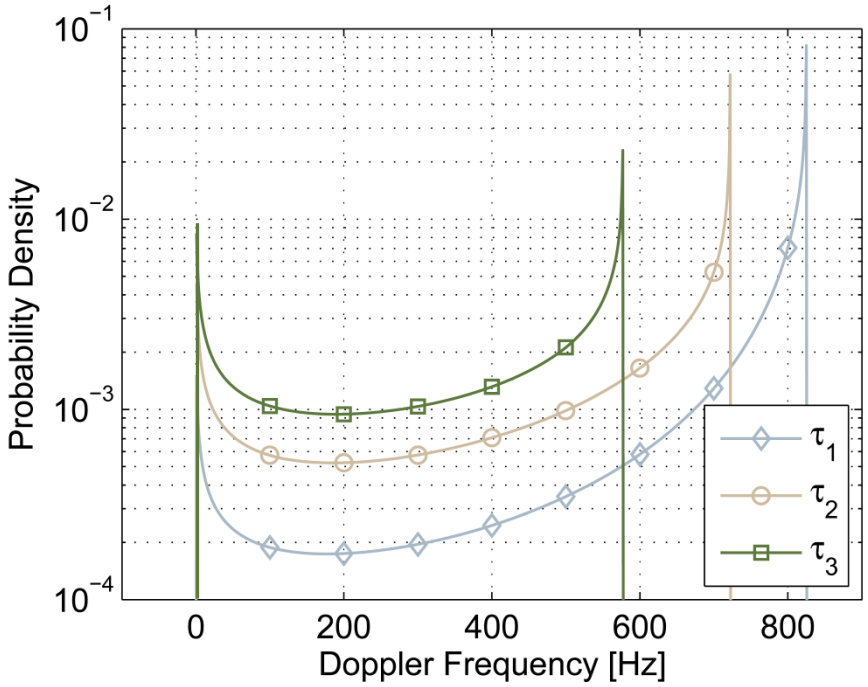

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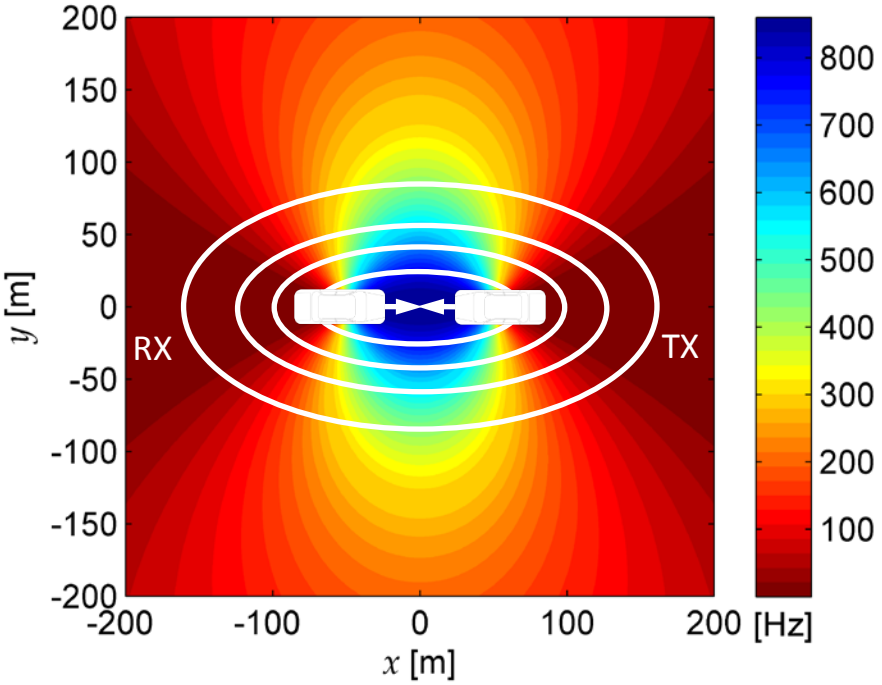

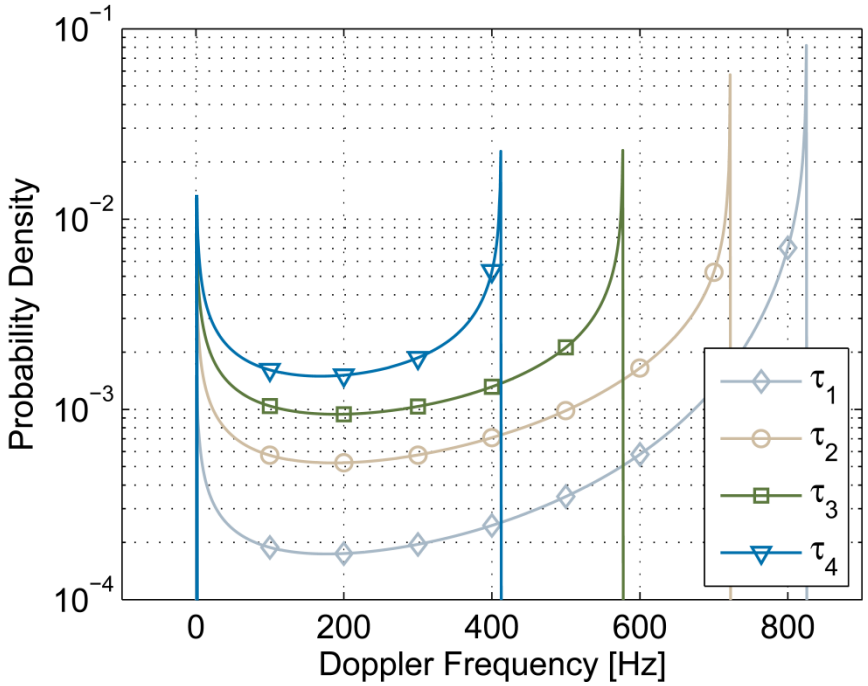

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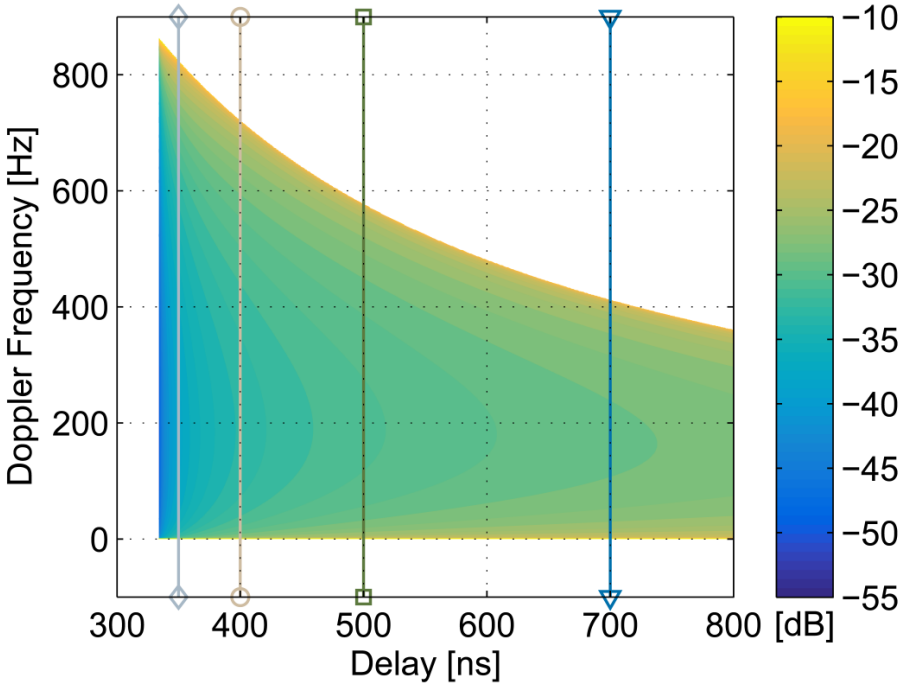

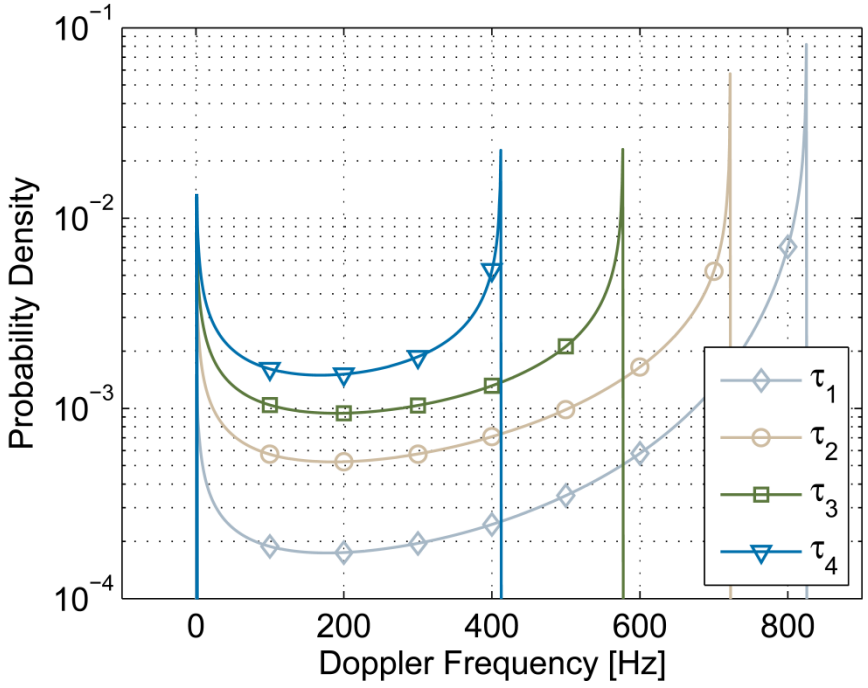

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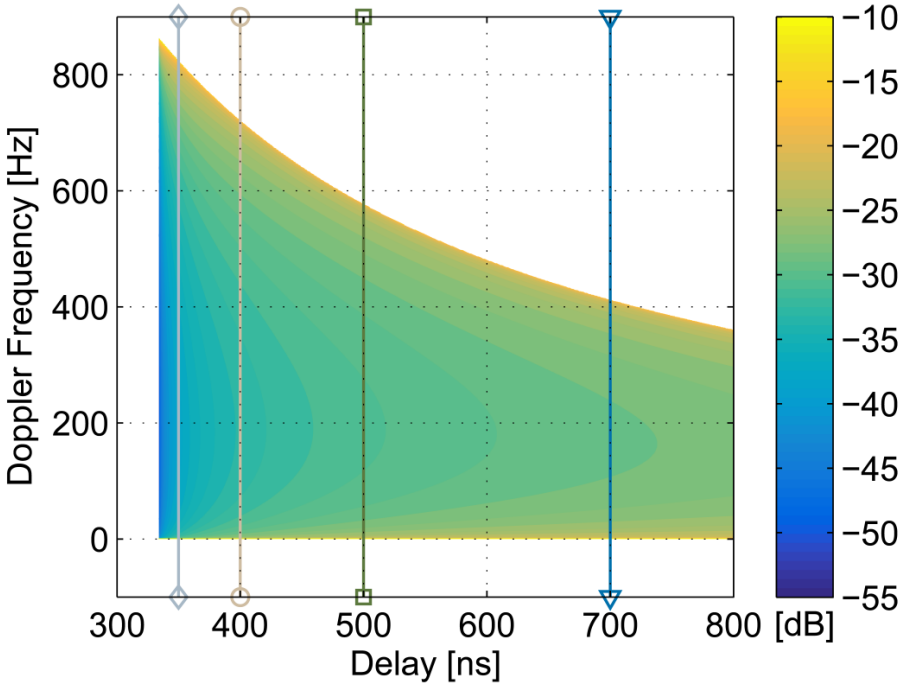
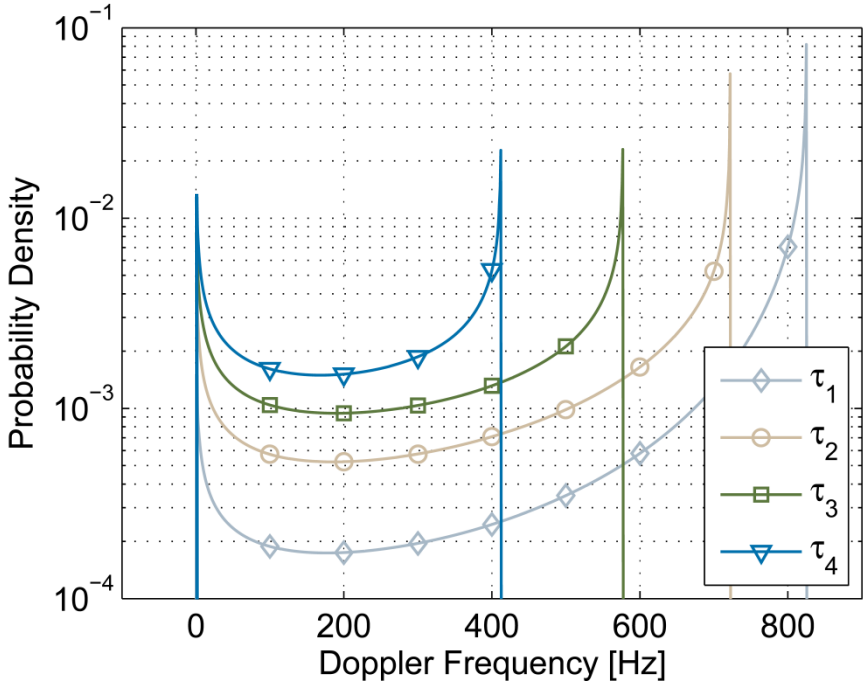
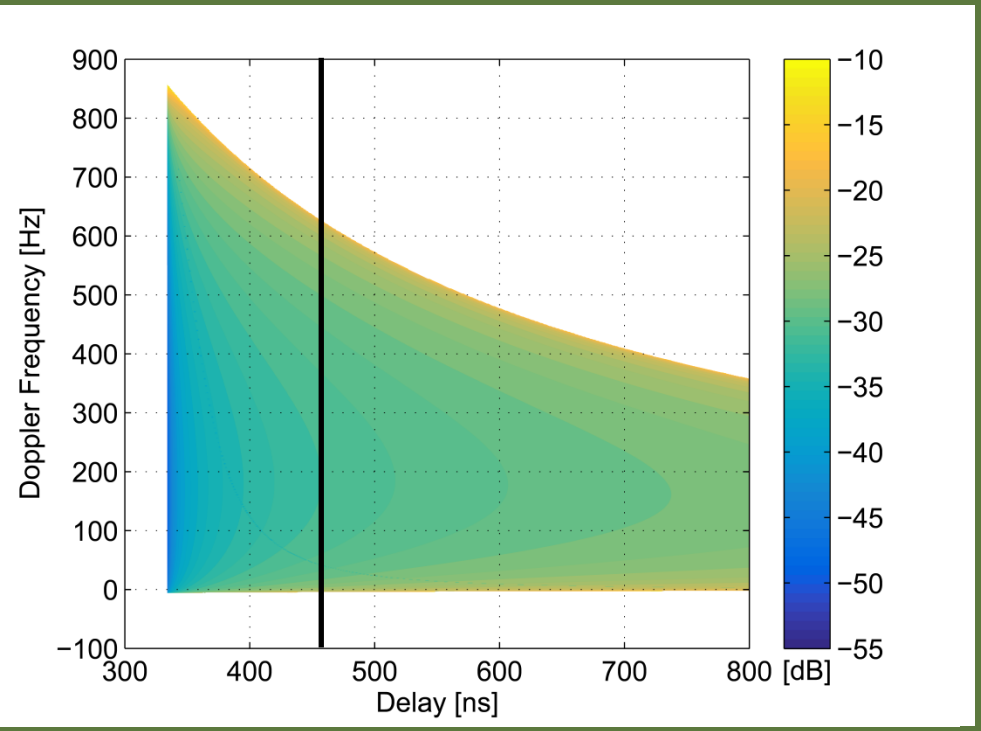
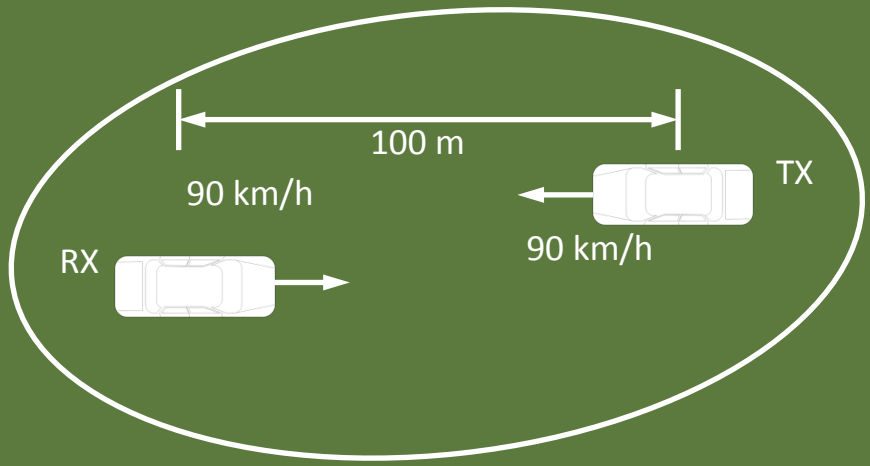




Doppler spectrum depends
on delay, velocity vectors, and Tx-Rx distance

V2V-Channel: Influence of Finite Scattering Areas





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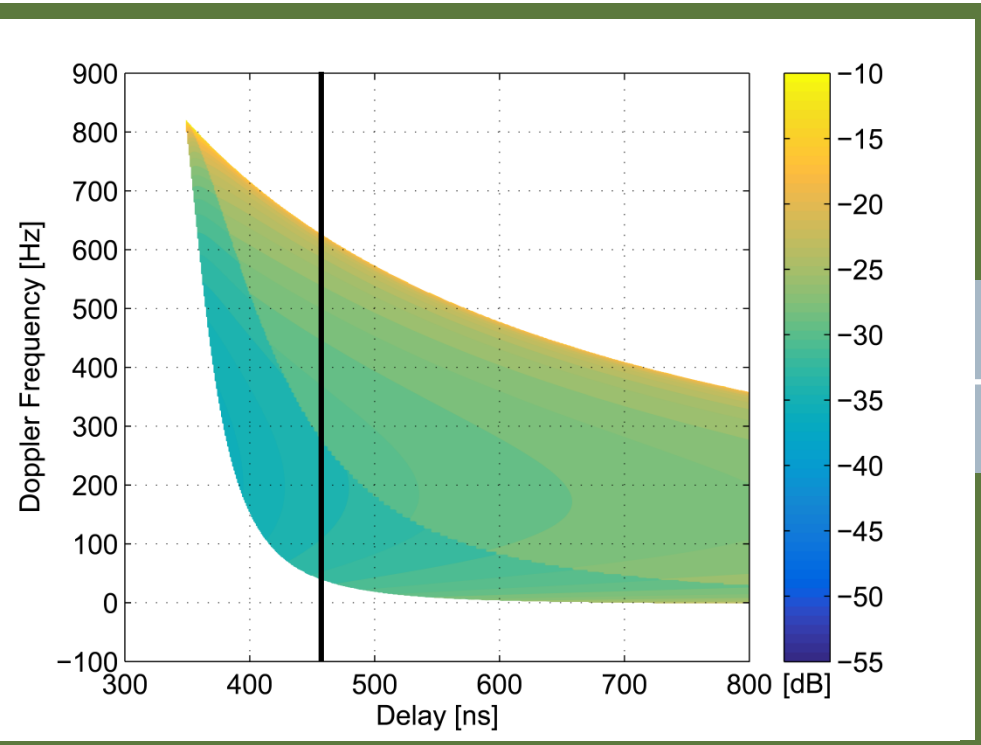

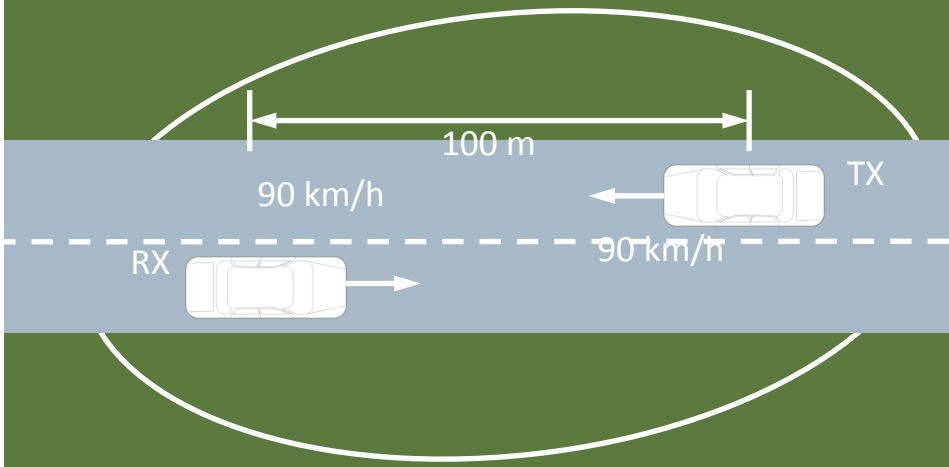

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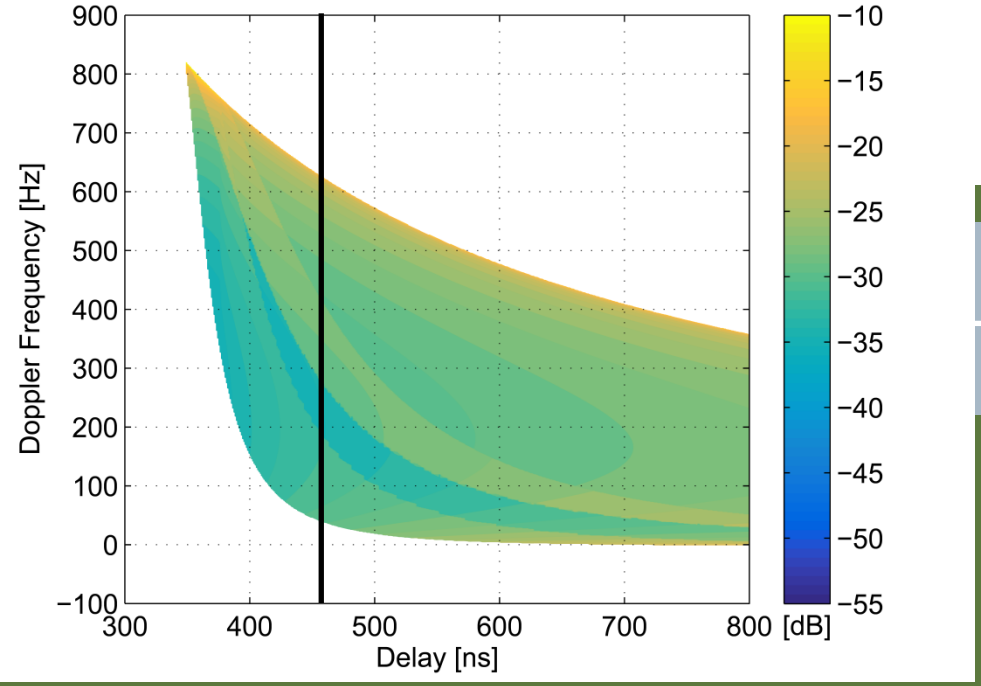

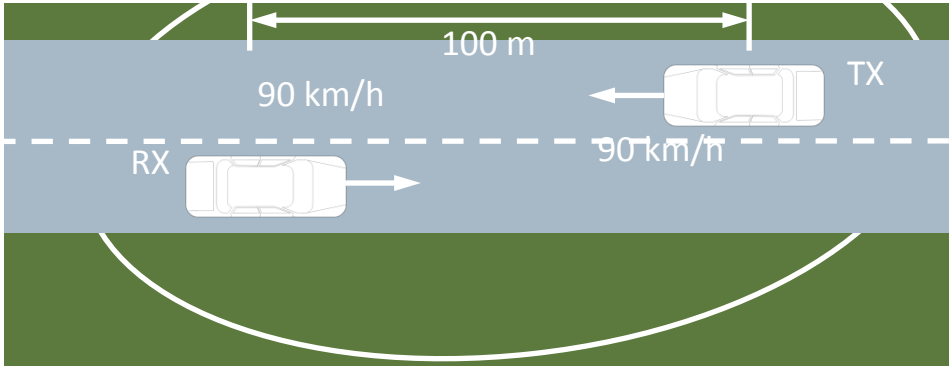

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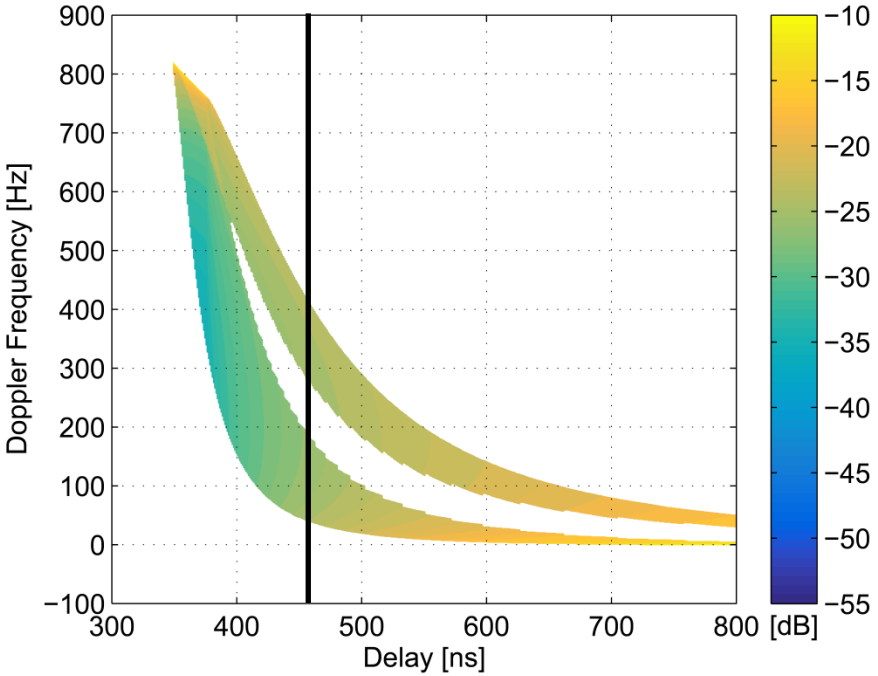
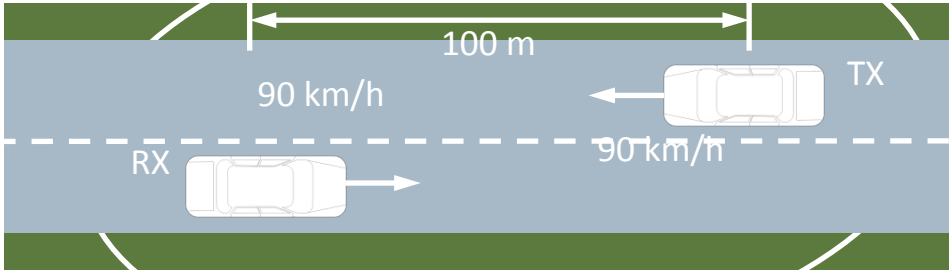
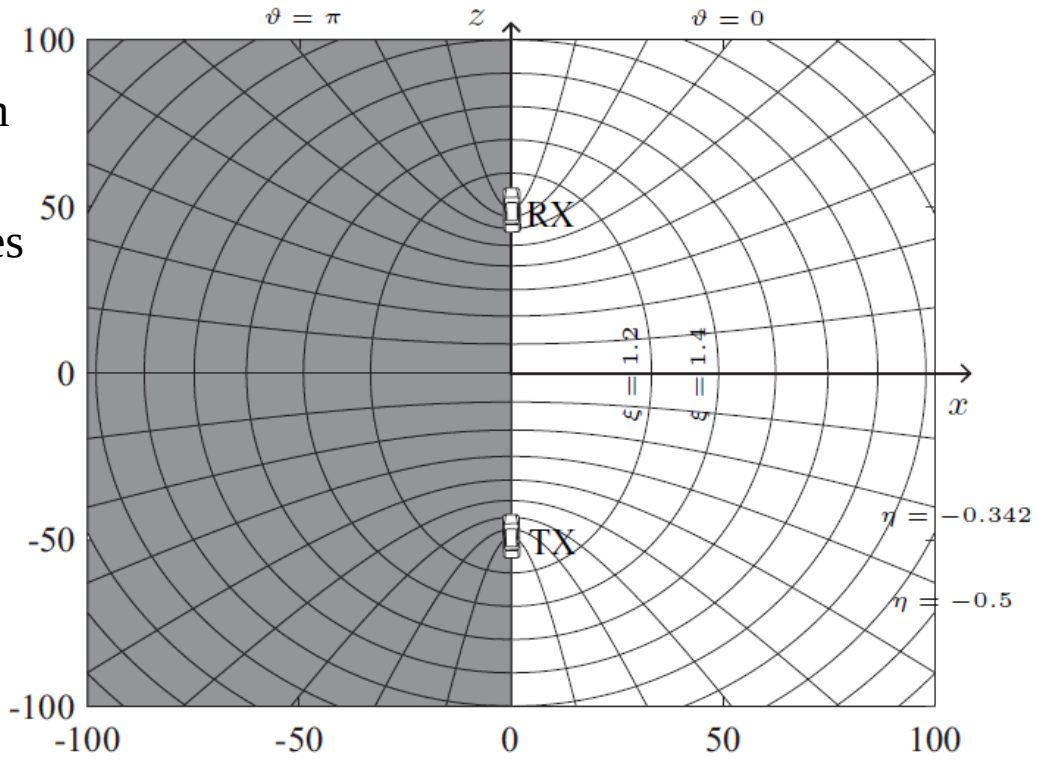




V2V-Channel: Theoretical GSCM based on *Prolate Spheroidal Coordinate System*

- Exploit symmetry of problem by using adequate coordinate system
- Separate coordinate ξ to describe constant delay resulting in ellipses
- Allows a delay-dependent description of the Doppler frequency
- No trigonometric functions

Algebraic analysis is possible!

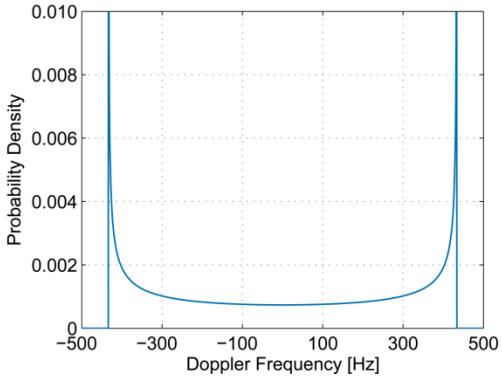


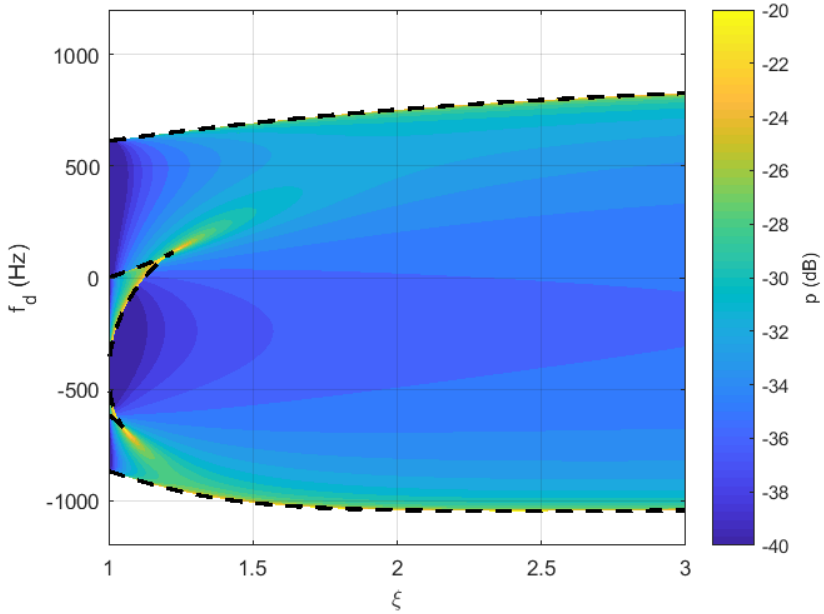
[10] M. Walter, D. Shutin and A. Dammann, "**Algebraic Analysis of the Poles in the Doppler Spectrum for Vehicle-to-Vehicle Channels**," in *IEEE Wireless Communications Letters*, vol. PP, no. 99, pp. 1-1.

V2V-Channel: Theoretical GSCM based on *Prolate Spheroidal Coordinate System*

Algebraic Analysis of Poles in the Doppler Spectrum:

- Poles determine the limiting frequencies of the spectrum
- Theorem: In V2V channels the Doppler spectrum caused by single-bounce scattering can possess up to six distinct real poles.
- Polynomial of degree 6 to resolve for the spectrum poles





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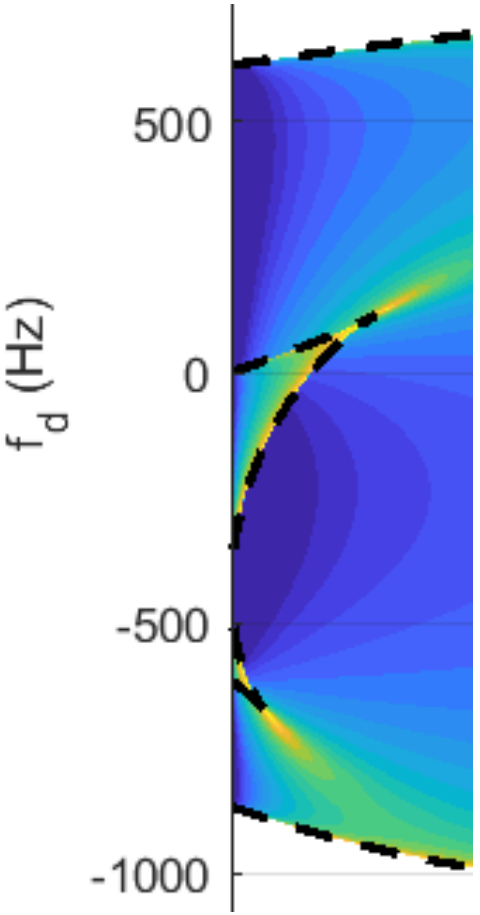
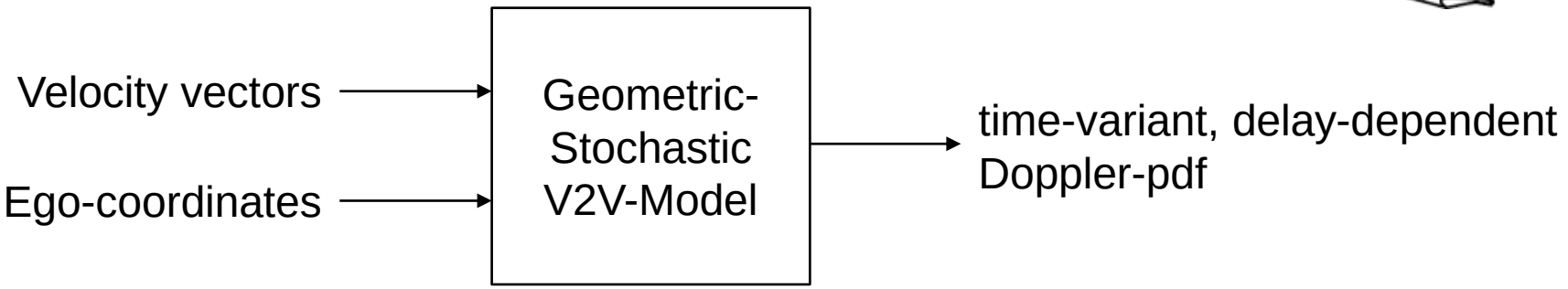


V2V-Channel: Theoretical GSCM based on *Prolate Spheroidal Coordinate System*

- More realistic compared to (over-)simplifying models
  - ➔ time-variant (geometry-dependent) and delay-dependent Doppler spectrum
- Computational efficient

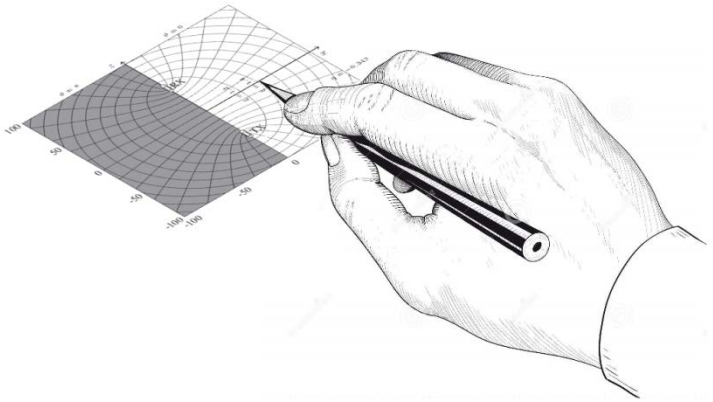


Easily applicable for

- simulation and emulation (PHY, MAC,…)
- performance evaluation for NGV

Summing up…

- Precise theoretical geometric-stochastic channel model for non-stationary vehicle-to-vehicle channels
- Applicable for simulations and (enhanced) performance evaluation
- Suitable software is under construction…



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[7] M. Walter, D. Shutin and U. C. Fiebig, "Delay-Dependent Doppler Probability Density Functions for Vehicle-to-Vehicle Scatter Channels," in IEEE Transactions on Antennas and Propagation, vol. 62, no. 4, pp. 2238-2249, April 2014.

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[10] M. Walter, D. Shutin and A. Dammann, "Algebraic Analysis of the Poles in the Doppler Spectrum for Vehicle-to-Vehicle Channels," in *IEEE Wireless Communications Letters*, vol. PP, no. 99, pp. 1-1.